GROUNDWATER AND PUBLIC POLICY LEAFLET SERIES

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The Groundwater Policy Education Project is a joint effort of Cooperative Extension, the Freshwater Foundation, and the Soil and Water Conservation Society. These organizations joined together to create educational materials that would increase the abilities of citizens and local and state officials to make informed groundwater policy decisions.

#4: THE COSTS OF GROUNDWATER CONTAMINATION

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Determining the true cost of a groundwater contamination incident requires assessment of the value of the groundwater resource in question. A clear understanding of these value sources and resulting contamination cost estimates suggests important implications for researchers and policymakers.

OPPORTUNITY COST: WHAT IT IS AND HOW IT IS DETERMINED

Resources are valued primarily for the services that they provide. For example, water can be used for irrigating cropland, washing clothes and drinking. The amount people are willing to pay for clean water depends on the nature of these uses and the availability of substitute resources that could provide

the same services. Also, resources not being used currently may have value to people who expect to use them in the future or who wish to ensure that they are available for others to use. Finally, there may be those willing to pay for preservation of rare resources merely to ensure their continued existence, regardless of plans for actual use. Using this reasoning, economists refer to the sources of value for a resource as use, option, and existence or bequest values.

If a valuable resource is damaged or lost, then the cost of that event can be determined by examining the change in the services available from the resource. In response to the loss or damage, the services can be restored by the least-expensive alternative methods or the services can be foregone. The extra cost of the leastexpensive response option represents the cost of the adverse event.

The words use and service include indirect effects as well as direct services provided by the affected resource. For example, groundwater may serve as a drinking water supply and as a recharge source for a wetland. Since the wetland provides services such as recreation,wildlife habitat, spawning grounds

and lower-level food chain functions, it has value in addition to the value of drinking water. The extra cost of restoring these functions or loss of those functions is part of the "cost" of groundwater contamination.

In theory, these principles are straightforward to apply. For any contamination incident, the first step is to gather information on the physical characteristics of the event, including the type of contaminant, its concentrations in the aquifer, the areal extent of the pollution, and its expected path of movement. This information tells us what can be done to respond to the incident. The basic choices include some combination of the following:

- Contain the original source.
- Treat the contaminated water before use.
- Remediate the water in the aquifer before use.

- Provide an alternative clean water supply.
- Continue use of the contaminated water and suffer the health, welfare or ecological effects.
- Forego use of the water and lose the valuable services it once provided.

The next step is to assess how the water had been used and how it could be used after taking one or more of the response strategies listed. For example, even after treatment, some residual health risk may exist as compared with the "no-contamination" baseline. In this case, the extra cost of treatment should be added to the value of the residual health effects to determine the cost of the contamination incident.

From an efficiency standpoint, the best strategy, or combination of strategies, is the one with the lowest overall extra cost. The extra cost of this chosen "cost-effective" strategy represents the cost of the contamination incident. That is the opportunity cost borne by society in the event of contamination.

With this conceptual framework in mind, it is clear that two general factors together determine the cost of groundwater contamination:

- the ways in which water was being used or was expected to be used in the future;
- the physical characteristics of the setting that constrain responses available to regain lost uses or prevent related damages to human health and the environment.

SOURCES OF VALUE FOR GROUNDWATER

The Use Value of Groundwater

We begin by reviewing the uses of groundwater, because it is the actual or expected use of the resource that primarily gives it value. In some cases, there may be no acceptable way to restore the lost services of groundwater. In these cases, the cost of the incident is equal to the net benefits of the aquifer when it was clean. There are a number of use values that may be lost due to contamination. In most cases, however, cost-effective remedies are available, and the added cost of these remedies represents the cost of the incident rather than the use value itself.

Municipal Use Value

Although municipalities account for only 10 percent of water withdrawn in the United States, such uses are generally thought to be the most important and highly valued. Municipal supplies provide for residential use as well as for fire-fighting and other outdoor uses. In most systems, water rates are not set in competitive markets, and often rates are not designed to cover the costs of development, treatment and delivery. As a result, it has been difficult to conduct statistical studies of the willingness to pay for potable supplies of municipal water.

A survey of literature on water demand reveals that the value of water, at the margin, varies widely across different regions. In a survey of how much consumers would be willing to pay to avoid a 10 percent reduction in water use, the answers (in 1988 dollars) ranged to as high as the equivalent of about $5 per year per household. (90 percent of households in the United States pay less than $110 per year for water service.)

Industrial Use Value

Industrial use accounts for about 10 percent of water withdrawn in the United States, with the dominant use being for cooling. Because many industrial processes are not sensitive to the quality of the water, contamination may not preclude such uses. If water use must be curtailed, recycling and reuse costs range from about $10 to $100 per acre-foot. Recycling and extra quality treatments may push the cost up to $400 per acre-foot.

Irrigation Use Value

Some of the most productive farmland in the country is irrigated land in the West. Many researchers have assessed the value of extra crop yield attributable to irrigation. These "marginal value products" for water vary widely in value from near zero to more than $100 per acre-foot, depending on the crop and the geography of the area. The wide range of values clearly shows that water is not marketed and transported easily to the point of its highest valued use. Rather it is used in activities of very different productivity and these "inefficient" uses are protected by legal and institutional barriers.

As water markets mature, we can expect to see only higher-valued water uses as well as the price reflecting a more uniform marginal value. As water rights become more "transferable," municipal users will bid up the price, and less water will be used in irrigation.

Option Value

Besides actual use value, water supplies also may be valued for potential future use. There is much public interest in protecting groundwater for the future. A study that assessed residential willingness in Cape Cod to pay to protect potable groundwater from possible nitrate contamination focused on several scenarios representing different levels of risk of future contamination. The present value of protecting the aquifer ranged from $5 million to $25 million per 1000 households. This represents a willingness to pay from $500 to $2500 per year per household for groundwater protection.

In summary, use and option values can be viewed as an approximation of the cost of contamination. Most contamination incidents can be managed at a low-enough cost that uses will not be foreclosed.

Existence Value

Finally, society may desire to protect groundwater as a resource with intrinsic value separate from any desire to avoid the direct costs associated with contamination. Because this existence value also is lost when groundwater is contaminated, it may motivate even greater protection efforts.

PHYSICAL ASPECTS OF CONTAMINATION

Three physical characteristics of groundwater are of particular importance when considering cost. First, groundwater usually moves very slowly through an aquifer. As a result, natural cleansing of an aquifer through recharge and dilution can take many years. A simulation study of a Superfund site in Woburn, Massachusetts, suggests that 40 years of natural cleansing still would not result in water that met U.S. Environmental Protection Agency (EPA) drinking water standards.

The second aspect of groundwater that influences the cost of contamination is the fact that it is underground. Although the science of hydrogeology has advanced greatly in the last several years, it still is very difficult and costly to identify the exact area and expected path of a contamination plume. In such cases, choosing a cost-effective and protective response strategy is a serious dilemma.

A third consideration is that groundwater is no different from any other water. Therefore, treatment or replacement of contaminated water often may represent the cost-effective strategy for managing the event.

COSTS OF CONTAMINATION

If contamination of groundwater is not detected, then adverse health and ecological effects may result. For example, contamination of surface water by groundwater recharge can damage spawning grounds, upset food chains and affect habitat in many ways that affect biodiversity and other measures of ecosystem health. These costs are difficult to quantify, although they may be severe.

When contamination of a drinking water supply is detected, a response strategy can be fashioned from available options. Detection itself can be costly, due to the need for monitoring wells and laboratory analysis. For example, if a private well is threatened with possible contamination from agricultural chemicals, biannual testing would cost $100-$300 per year. If larger areas are threatened, the drilling of new monitoring wells may cost several thousand dollars each, and more elaborate sampling may be necessary.

Adverse Health Effects

Although health effects are a principal concern in cases of undetected water contamination, there is significant uncertainty in any attempt to quantify and value such damages. Economic researchers have identified methods for measuring willingness to pay for reduced risk of adverse health effects across large populations. For example, observation of wage premiums paid to workers in risky jobs has allowed inference of the money-risk tradeoff. In addition, a variety of survey methods has assessed the subjective value of changes in such risks. A survey of recent literature on the valuation of small changes in the risk of death due to such accidental causes as pollution suggests that the value of a "statistical life" saved ranges from $1 million to $7 million.

There is less empirical evidence on the value of avoiding nonlethal health effects. A rough but practical approach is to use the costof-illness approach for valuing nonlethal effects. Costs include direct medical treatment costs, whether covered by insurance or not; the value of lost work; and the value of lost leisure time. These costs vary according to the nature of the illness, its severity, duration, possibility of recurrence and other factors.

Containment and Remediation Costs

Source control can mean stopping an activity like agricultural chemical use; removing a source such as an underground storage tank; injecting barrier walls underground around a source; sealing the surface area above a source to reduce water infiltration and leaching; or controlling water pumping and reinjection to prevent groundwater from flowing out of the area. Costs for containment action can vary widely depending on site characteristics, the type of contaminant, and the extent of the plume.

For example, analysis of containment options at a hypothetical 10acre landfill included$4 million for sealing the bottom, $1.4 million for installing a grout curtain, and $200,000 for an injection/extraction barrier. The average cost of remedial action at Superfund sites has been estimated to be $8 million. In many cases the cost of providing alternative water supplies until remediation is complete must be added to other costs to determine the total cost of the contamination incident.

Treatment

Effective removal of many contaminants can occur through central treatment technologies in municipal systems or by point-ofentry/point-of-use technologies in rural residences with private wells. Central treatment often is the least-expensive response to a contamination incident. Such treatment can add several hundred dollars per year to the household cost of water supply in very small systems and from $2-$50 per year to the annual household bill in large systems.

Replacement

For large public water suppliers facing contamination of a small part of the total source supply, replacement of the contaminated supply is often a fairly inexpensive response strategy. Construction of new wells can provide water ranging in cost from a few cents per 1000 gallons in very large systems to $3 per 1000 gallons in the smallest systems. A new well for a single household can cost $5000 to $7000, depending on diameter, depth and other site characteristics. Hookup of a household to a public system can cost $12,000

or more, depending on distance to the water main, plus water payments.

An Estimate of Nationwide Contamination Costs

EPA prepared an assessment of the water supply replacement cost due to groundwater contamination potentially resulting from nine types of major point sources. The total present value of resource damage from these sources was estimated to be greater than $28 billion. This figures does not include costs for monitoring or management of groundwater contaminated by such nonpoint-sources as agricultural chemicals or urban runoff.

Estimated national damages range from no cost for combustion of hazardous waste to $8 billion for National Priority List (Superfund) sites and more than $15 billion for underground storage tanks. On average, the study estimated resource damages at $9.7 million for individual Superfund sites; $300,000

to $400,000 each for land disposal sites of various kinds; and $11,000 each for underground storage tanks. The great number of underground storage tanks accounts for their large contribution to the national problem.

AVERAGE TREATMENT COSTS FOR GROUNDWATER SYSTEMS

Type	Treatment System Size (number of households served) 25-100	25,000-50,000	500,000-1 million
	-----------cost/household/year---------------		
Disinfection	$175	$4	$2
Granular activated carbon	$217	$21	$11
Multiple (disinfection, corrosion control, ion exchange and granular activated carbon)	$723	$89	$56

NOTE: Preliminary estimates provided by the EPA Office of Drinking Water. Subject to revision. Costs are expressed in 1988 dollars. Household cost assumes use of 140 gallons per day per capita for all uses and 2.5 people in household.

IMPLICATIONS FOR POLICY

A primary reason for developing estimates of the costs of groundwater contamination is to enlighten decision-makers about the importance of preventive measures for groundwater protection. Because of the difficulty of cleaning up contaminated aquifers, it is argued that prevention is better than remediation. In carrying out an analysis comparing prevention with remediation, it is tempting to focus on the costs of contamination and compare them with the costs of a prevention program. This approach, however, can lead to serious errors.

No prevention program is perfect, so there is always the possibility of groundwater contamination despite protective measures. Conversely, contamination of groundwater does not occur around every potential point source. Therefore, damages from contamination only occur sometimes, with a probability between zero and one.

In comparing the costs and benefits of prevention programs with those of remediation, replacement or treatment programs, it is essential to adjust the cost/benefit numbers by the probability of their actual occurrence. In other words, cost/benefit analysis always should occur within an expected value framework. In addition, because costs and benefits are likely to occur at very different points in time, all values should be discounted to the same point in time to make them comparable.

While groundwater contamination now occurs nationwide, each incident typically affects only a small part of the relevant groundwater system. Because of the wide dispersion of many small events, the cost of each incident seems small. But, as demand for potable water increases, and if at the same time contamination becomes more widespread, the opportunities for finding alternative sources will decrease and the extra cost of contamination incidents will rise quickly. State and regional authorities need to develop water plans for a reasonably long planning horizon, as well as strategies to protect both current and future supply sources.

IMPLICATIONS FOR RESEARCH

Recognizing that the cost of contamination depends on the availability of substitutes and treatment technology, two lines of research require further pursuit. First, we need better forecasts of water demand to predict more accurately the scarcity of new supply and the associated cost of replacement. This research should include estimates of the price elasticity of water demand and the possible effect on demand of more rational cost-based pricing structures.

Second, we should encourage research and development techniques for in situ remediation. Pump-and-treat strategies result in very slow remediation of aquifers. Biological or chemical methods of purifying water in the ground could decrease greatly the cost of cleansing a contaminated aquifer.

Groundwater contamination is costly, and remediation processes can be complex--and sometimes impossible. Researchers need to continue developing more effective - and efficient - remediation techniques, and policymakers need to focus on reasonable, cooperative, long-term strategies to protect

both current and future groundwater supplies. This combined focus on effective remediation and enhanced protection will be critical to assuring the continued availability of adequate groundwater supplies for the future.

This paper represents the views of the authors alone and should not be interpreted as a statement of the U.S. EPA or RCG/Hagler, Bailly, Inc.

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from the Soil and Water Conservation Society, 7515 N.E. Ankeny Road, Ankeny, Iowa 50021-9764, for $12.]

RECOMMENDED FURTHER READING

The Magnitude and Costs of Groundwater Contamination from Agricultural Chemicals. 1987. Elizabeth G. Neilson and Linda K. Lee. Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

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